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FLOOD CONTROL IN THE MIDDLE MISSISSIPPI

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WATERWAYS DIVISION

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FLOOD CONTROL IN THE MIDDLE MISSISSIPPI[1]

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SYNOPSIS

The problem of floods is prevalent in all river valleys. In the Middle Mississippi, it is of major importance in view of the industrial and agricultural development of the valley. The efforts of local interests through organized levee districts, supplemented by major assistance under the Federal flood control policy, will provide an economical and practicable degree of protection for both industry and agriculture.

INTRODUCTION

Flood plains of great rivers have always offered special inducements to early settlers: (1) the fertility of the soil; (2) abundant water supply; and (3) transportation. The Middle Mississippi was no exception. In the early part of the 18th century, settlers and fur traders were pushing westward from the American colonies along the Atlantic, and from French colonies in Louisiana and Canada.

Early settlements were established along what is now known as the Middle Mississippi River—that stretch of the Mississippi between its two largest tributaries, the Ohio and the Missouri—French, as early as the turn of the century. In 1763, all of the eastern side of the flood plain passed under American control, but it was not until the completion of the Louisiana Purchase in 1803 that jurisdiction of the entire flood plain passed to the United States. Because of the earlier division of sovereignty, the wide flood plains on the eastern bank of the Middle Mississippi became known as the "American Bottoms." Despite this appellation, geographic names in the flood plain attest to the fact of early Indian and French settlements—Cahokia, Prairie du Pont, Carondelet, Fort Chartres, Prairie du Rocher, Kaskaskia, Bois Brule, Cape Girardeau, and many others.

As the American Bottoms developed extensively in the 19th century, settlers of many nationalities migrated from Europe and from the eastern seaboard and founded many other communities throughout the American Bottoms. Many of these settlers were of German extraction, who brought their extensive knowledge of farming and played a prominent role in the development of a rich and prosperous farming country. Paralleling the agricultural development of the American Bottoms, the eastern railroads pushing westward converged at the Mississippi River at a point opposite St. Louis which had been founded on the western side of the Mississippi by the French merchant and fur trader, Pierre Laclede Linguest in 1764 and which, by the middle of the 19th century, had expanded to a thriving inland metropolis as he had predicted.

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Floods of Record

While St. Louis and the American Bottoms were growing side by side, the Mississippi River, which had served and continued to serve them so well, sometimes turned on them and lashed back with its fury of flood waters, over-running their farms, destroying their crops, washing away their buildings and showing them who still was "the master." One of these occurred in 1785 and, while the records are fragmentary, there is sufficient evidence to say it was equal to the accepted flood of record, which occurred some 60 years later in 1844. Of this latter flood, excellent records are available to establish it as the maximum of record, reaching a stage of 41.3 feet on the St. Louis gage, with a computed maximum flow of 1,300,000 cubic feet per second. At this point in the development of the valley, improvements by the settlers had not reached a stage which offered much impediment to the widespread flow of the flood waters.

Floods of great volume have occurred with a curious pattern of two or three floods occurring in a short period of years—in 1851, '55 and '58; in 1881, '82 and '83; in 1892; in 1903 and '04; in 1908 and '09; in 1927; in 1943, '44 and '47; and again in 1951. The second greatest flood of record in measured flow and also in stage up to that time occurred in 1903. Despite the damage and discouragement which must have followed the numerous floods from 1844 to 1903, great strides had been made toward the development of the American Bottoms. Not only had St. Louis developed into a bustling city, but its counterpart, Illinoistown on the eastern bank of the Mississippi, now called East St. Louis, was developing into an industrial center located at the western terminus of the main line eastern railroads. The two cities were joined by Eads Bridge, completed in 1874, and shortly after by the Merchants Bridge in 1890. In due time, additional bridges were constructed until at this time a total of 10 bridges span the Mississippi River between Alton, Illinois, and Cape Girardeau, Missouri. The industrial and agricultural development of the American Bottoms was well established by the turn of the century although the effect of floods was certainly a delaying factor in that development.

Early Local Efforts

Protection of the valley was accomplished by efforts on the part of industrial developers and the agricultural settlers to protect themselves and their investments against the ravages of these recurring high waters. Much had been done through individual effort and association of groups to construct levees to protect a large part of the areas. However, there was no unified endeavor—levees were constructed not to a uniform grade and standard cross-section but to the extent that individual capabilities and resources permitted. The earliest endeavor toward unified action was the organization of the Columbia Drainage and Levee District in 1880. This district included approximately 13,000 acres or excellent farmland in Monroe County, Illinois. It has had 75 years of continuous operation and is an excellent example of what a small group can do to protect themselves through cooperation and organization. Following shortly after the Columbia district other levee districts were organized and additional areas were protected. The flood of 1903, however, indicated to all that their efforts to date had not been enough. In that year, every levee from the Missouri River to Cape Girardeau was overtopped or crevassed and every acre of bottom land was flooded. While detailed records are lacking, it is generally conceded that this flood caused the

greatest single damage up to that time and in turn aroused greater interest in securing adequate protection. Shortly after this flood the entire area centering around the industrial cities of Granite City, Madison, Venice and East St. Louis was organized into the present East Side Levee and Sanitary District, containing approximately 70,000 acres. A good plan of improvement was drawn and subsequently constructed. The Sanitary District adopted a levee grade equivalent to approximately 45 feet on the St. Louis gage to provide protection not only against a recurrence of the flood of 1903, which had reached a stage of 38 feet, but also against the great flood of 1844. Meanwhile, the areas downstream and upstream were endeavoring to improve their levee protection but none were able to adopt as good a standard as that of the East Side District.

Federal Assistance

It was at this stage of development that Federal aid through the medium of the Mississippi River Commission was first extended to the local groups under the provisions of the Flood Control Acts of 1917 and 1923. Under these Acts, the Federal Government agreed to bear two-thirds of the construction cost of economically sound local protection projects, if local interests would furnish the other third, as well as all of the necessary rights-of-way and agree to maintain the levees after their completion. Essentially the same provisions were retained for this portion of the river in the better-known Flood Control Act of 1928, which was enacted after the historic flood of 1927 had caused widespread damage in the Lower Mississippi River. Under these authorizations, portions of the existing levees of some of the agricultural areas below East St. Louis were reconstructed to grades ranging from 2 to 6 feet above the flood of 1903. The portions so reconstructed were usually the weaker portions of the then existing levees and these in turn became the stronger sections, because of the higher grades and improved cross-section. However, as late as 1935, the levee districts had not taken full advantage of the aid thus extended, and all had varying degrees of protection.

In 1936, Congress adopted a new Flood Control policy aimed at the flood problem on a national basis, as indicated in Section 1 of the Flood Control Act of that year which reads: "It is hereby recognized that destructive floods upon the rivers of the United States, upsetting orderly processes and causing loss of life and property, including the erosion of lands, and impairing and obstructing navigation, highways, railroads, and other channels of commerce between the States, constitute a menace to national welfare; that it is the sense of Congress that flood control on navigable waters or their tributaries is a proper activity of the Federal Government in cooperation with States, their political subdivisions, and localities thereof; that investigations and improvements of rivers and other waterways, including watersheds thereof, for flood-control purposes are in the interest of the general welfare; that the Federal Government should improve or participate in the improvement of navigable waters or their tributaries, including watersheds thereof, for flood-control purposes if the benefits to whomsoever they may accrue are in excess of the estimated costs, and if the lives and social security of people are otherwise adversely affected." Under this policy the Federal Government was to bear the cost of construction and local interests would furnish the rights-of-way and hold and save the United States free from damages due to construction and maintain and operate the works after completion. In cases of special benefit, such as land enhancement due to changed land use, local participation in the construction cost, based on the ratio that special benefits

bear to general benefits, would also be required under existing legislation. In this Act, Congress authorized for reconstruction the levees of 14 local protection projects between Alton, Illinois, and Cape Girardeau, Missouri. In subsequent flood control legislation, Congress authorized 8 additional local protection projects, including protection for the cities of Cape Girardeau, Missouri, and Alton, Illinois, making a total of 22 local protection projects in the Middle Mississippi River.

Design Criteria

Engineering studies prior to the Flood Control Acts of 1936 and 1938 indicated that two degrees of protection should be considered, one for the larger agricultural areas south of East St. Louis, and a greater protection for the industrial areas centering around East St. Louis. Economic studies indicated that while each separate agricultural area would not provide the same benefit/cost ratio for a uniform degree of protection, the variations in that ratio were not sufficiently great to warrant adoption of an independent grade for each project. The studies indicated that uniform protection against a flood which might be expected to have a frequency of occurrence of once in 50 years would approach the maximum degree of protection which would be economically justified in each project and would result in benefit/cost ratios ranging from 1-1/2 to 1, upward.

The industrial areas extending from Alton south to Dupo and embracing three organized levee districts—the Wood River Drainage and Levee District, the East Side Levee and Sanitary District, and the Prairie du Pont Levee and Sanitary District—total approximately 97,000 acres, a large part of which is occupied by industry of all types, including the manufacture of paper, glass, ammunition, steel plate, reinforcing steel, zinc, aluminum, chemicals, fertilizers, as well as oil refineries, grain elevators, cold storage plants, and the greatest concentration of railroad terminals and yards along the Mississippi. The three industrial areas have a total population of 213,000. For this major industrial area a degree of protection somewhat greater than that adopted for the adjoining agricultural areas was definitely indicated. A primary factor to be considered was the record of peak discharges which had occurred in the past. As stated earlier, the largest known flood occurred in June 1844, with a peak discharge at St. Louis of 1,300,000 cubic feet per second. Four floods with peak flows slightly exceeding 1,000,000 cubic feet per second have occurred since 1844. Flood frequency investigations indicate that a natural peak discharge of 1,300,000 cubic feet per second can be expected at St. Louis on an average of once in 200 years. Studies of the flood producing potentialities of the great drainage basin above St. Louis indicate that floods greater than that of record may occur. By transposition of the pattern of a severe storm which occurred in the adjoining Arkansas River basin in 1943, over the lower section of the Missouri River basin and the Upper Mississippi River basin, a natural peak flow of 1,900,000 cubic feet per second at St. Louis would be possible. For several years a program of reservoir improvements in the basin above St. Louis, including storage for flood control, has been in process. However, the program will need to reach an advanced stage of construction and include, particularly, reservoirs to control a run-off of the lower Missouri tributaries before it will dependably affect substantial reductions in major floods at St. Louis. A study of the effects of reservoirs on what might be the maximum flood from such a transposed storm shows that a reduction of approximately 400,000 cubic feet per second could be expected. In view of the time required for the ultimate

development of the reservoir program and the immediate need for increased protection, it was considered that protection for the industrial areas would have to be provided by local levees of sufficient height to give reasonable protection without dependence on the additional protection which would eventually come with the development of the reservoir program. It was considered that the industrial levees should provide protection against the flood of record with an adequate freeboard above water surface.

Variations in Rating Curve

While earlier hydraulic studies had indicated that this flow would reach 47 feet on the St. Louis gage, the results of the 1947 high water confirmed by similar conditions in 1951 indicated that under certain conditions and with the ultimate completion of the 22 projects, a higher stage would be required to pass the same flow. Model studies were made, the results of which confirmed hydraulic computations which showed that under the 1947-1951 conditions, 1,300,000 cubic feet per second would reach 52 feet on the St. Louis gage. Data covering a long period show a continued general increase in stages at St. Louis in relation to discharges of large floods. Encroachment on the flood plain by man-made works, including the construction and strengthening of levees in the vicinity of, and downstream from, St. Louis has been a primary cause of this general change in the rating curve. Most of the protectible area of the flood plain has been leveed and all of the levees except three withstood the flood of 1951. It was concluded, therefore, that the rating curve of 1947-1951 was a reasonable indicator of the general future relationships between flood stages and discharges at St. Louis. Independently of the general change which had taken place, the rating curve varies, and will no doubt continue to vary, with the characteristics of the flood in progress at the time. Investigations indicated that relatively higher stages can be expected when a large percentage of the flow comes from the Missouri River, which carries a large bed-load of material; during summer floods; and also when the rate of rise of the flood wave is relatively slow. The flood of 1844 had those characteristics and all available evidence leads to the conclusion that the design flood would have similar characteristics. In any event, the general relationship of stage to discharge is of greater significance in determining a design flood stage than are the erratic characteristics of the rating curve, which vary for individual floods. It was therefore considered that a water-surface elevation of 52 feet on the Market Street gage should be adopted as the design stage generally corresponding to the design discharge of 1,300,000 cubic feet per second.

Construction Features

Construction under the present Federal assistance policy was started in 1937 and good progress was made until the national emergency preceding World War II caused cessation of work. The work which had been accomplished preceding World War II was extremely effective and saved the Columbia and Kaskaskia Island districts from inundation in the flood of 1943. These same two districts, together with the Perry County districts in Missouri, were also protected from the flood of 1944. Some emergency levee repair was performed under special authorizations of Congress following each of these two floods which, together with the resumption of work on the projects in 1946, served to protect 6 more districts from the flood of 1947. By 1951, progress had been sufficient to protect all but 3 of the 20 projects then authorized.

One of the important factors governing the construction of these projects has been the stabilization of the low-water channel of this reach of the Mississippi River. As a result of progress made during the late twenties and early thirties, the low-water regimen of the river had been well established and the bank lines stabilized. This permitted adoption of levee alinements with reasonable certainty that the protection would not be jeopardized by caving banks and channel realinements. In some cases, this has permitted protection to many more acres of rich agricultural land than would have been possible had the channel remained uncontrolled.
The pattern of work involved is much the same in the various projects. In general, the work consists of placement of semi-compacted earthwork totaling, in all, 125,000,000 cu. yds.; the installation of 215 gravity drainage structures through the base of the levees to provide gravity drainage for the interior run-off when river stages permit. These gravity drainage structures range in size from single 18-inch corrugated metal pipes up to quadruple 84-inch corrugated metal structures. Some rigid types are included, the maximum size of which is a triple 9 ft. x 9 ft. reinforced concrete box. The drainage structures are provided with a positive acting sluice gate on the riverside operated from a reinforced concrete headwall or, in some cases, concrete or metal gatewells.

Where improved highways and railroads cross the levees at elevation below the proposed levee crown, closure structures with gates, or stop logs, for emergency closure are provided. There are 47 closure structures in the 22 projects. In some cases, railroads having trackage outside the leveed areas have desired to take advantage of authorization in the Flood Control Act of 1946 whereby the Federal Government would bear the cost of relocation inside the leveed areas if the Railroad would agree to raise its tracks in the unprotected areas. The earliest contract of this type of work was entered into with the Missouri Pacific Railroad covering its main freight line extending from East St. Louis south via the Thebes Bridge over the Mississippi River to the south and southwest. Under this contract, the Railroad will be raised over the flank levees along 7 tributary streams and through 21 miles of unprotected areas, and will be enabled to operate without interruption by floods up to those having a frequency of once in 50 years. This particular railroad line (used also by the St. Louis-Southwestern Railway Lines—Cotton Belt Route) is one of the busiest in the midwest. During World War II, it is reported to have carried more national defence tonnage than any other similar line in the United States. Its northern terminus is the Dupo Classification Yard reported to be the third largest in the country.

Another feature of these projects in the underseepage control program which is being installed as soon as the levee structures are completed. The underseepage control program is designed to relieve or counteract the pressures which build up at the landside toe of the earthen levee embankment under head conditions which exist at stages equal to or approaching the design flood. These pressures are not dangerous to the stability of the levee where local foundation conditions are such that the pressure is counteracted by a thick impervious stratum extending to ground level. Where this impervious top stratum is relatively thin, however, the high head pressures at design flood stage are capable of breaking through the thin crust of the top stratum in the form of uncontrolled sand boils, which make the levee extremely vulnerable to failure. Significant features of alluvial geology such as beds of old sloughs and lakes merit special attention in any program of underseepage control.

Measures to combat the underseepage problem consist of:

(1) Extensive landside berms of selected material of sufficient height and width to contain or offset the underseepage pressure.

(2) Wells penetrating the principal water bearing aquifer to provide a method of releasing the pressure through controlled outlets.

(3) Where extremely shallow pervious strata exist beneath the top stratum, through which excessive seepage flow could cause piping and possible undermining of the levee, cutoff trenches backfilled with well compacted impervious material at the riverside toe of the levee will serve to eliminate this possibility and thus protect the levee.

In general, economics of the project rule out the possibility of constructing the levee entirely of selected earthen material. Consequently, the levee is usually constructed with the material at hand, taken usually from shallow borrow pits, lying riverward of the proposed levee. Foundation and borrow pit explorations and the results of laboratory testing of the available material, govern the design of the earthen embankment. In these projects the side slopes of the embankment generally vary from 1 on 3 to 1 on 3-1/2. In some cases, side slopes of 1 on 4 or flatter with lateral berms from 50 to 100 feet in width are required where the foundation consists of the weaker, wet plastic clays. In a few cases it has been found more practical to construct the embankment in two "lifts" with from one to two years intervening. Where this is possible, economy can be effected through a smaller cross-section than would have been possible if constructed in one operation.

Where space limitations govern the right-of-way, reinforced concrete floodwalls are substituted for levee embankments. Structural design of floodwalls is well established. In general, walls are limited to a maximum height of 25 feet and if not founded on rock, would have a sloping base. As the unit cost of such walls is from 15 to 20 times the corresponding cost of levees, economy dictates that the length of floodwalls be held to a minimum. In some cases it is possible to construct a combination section of earthen embankment surmounted by an I-type wall. Prudent design limits this type of wall to a maximum of 10 feet above the earthen section. It is interesting to note that of the 280 miles of flood protective works in the 22 projects only 2-1/2 miles of inverted T-type wall and 2 miles of combination I-wall and earthen embankment are included.

In 4 of the 22 projects which protect urban and industrial areas, that is, Alton, Wood River, and East St. Louis in Illinois, and Cape Girardeau, Missouri, where impoundment of interior run-off is not practicable, alteration or replacement of existing pumping stations and the provision of new stations, where new areas are protected, are included in the projects. Stations are designed to discharge the storm water run-off and sewage that is brought to the levee through sewers or drainage ditches. In general, the discharge capacity of the station should be sufficient to dispose of the run-off from a 30-year frequency rainfall, coincidental with blocked gravity drainage. In some cases advantage has been taken of available ponding areas immediately adjacent to the pumping station where the peak run-off can be decapitated, the excess run-off stored for a short period, and a smaller pumping capacity installed.

Construction Costs

The construction cost of the work involved in the 22 projects totals $102,000,000. Broken down by major items and by percentages, the

allocation of cost is as follows: levees—53%; floodwalls—13%; drainage structures—6%; pumping stations—7%; relocations—7%; closure structures—4%; relief wells—8%; service roads—2%.

The local cost of the work involved in the 22 projects amounts to approximately $7,000,000. The bulk of these costs, covering the right-of-way for the levees and borrow pits, amounts of 50%; damages and relocations of buildings, roads, railroad tracks, pole and power lines and fences, necessary to permit the construction of the levees, amounts to 35%, and the balance of the local costs is made up of engineering, legal, and other administrative charges. To date, the local cooperation in these projects has been excellent. In practically all cases the local levee districts have found it necessary to levy an assessment on the property in the district to cover the cost of participation. In only a few cases have the local districts been forced to resort to condemnation proceedings to acquire title to the right-of-way. Maintenance of the portions of the projects already completed and turned over to local interests has been performed satisfactorily and in accordance with maintenance manuals which are furnished by the Federal Government. The cost of such maintenance has been covered by an annual maintenance assessment on the landowners in each district. In Illinois a maximum annual maintenance assessment is established by the State statutes, but not all of the levee districts have found it necessary to assess this maximum. In Missouri, no statutory limit has been established, the assessment being set by the court having jurisdiction over the particular district.

Benefits

In the Flood Control Act of 1936 which established the basic Federal policy covering flood control, the Congress stated that the benefits should be in excess of the estimated costs. Economic studies are maintained for each project to permit the desired comparison of benefits and costs. These studies take into account all data gathered from flood damage studies made after recent floods of record. To supplement these, estimates are prepared from data available of the amount of damages that would be sustained for floods of various heights up to and exceeding the design flood. From stage-area curves and stage-frequency curves, damage-frequency curves are constructed. Using these damage-frequency curves, an average annual damage for conditions prior to the construction of the project is compared with average annual damage for conditions to be expected after completion of the project, to obtain the average annual benefit attributable to the project. In estimating damages, current crop prices are used, based on data released by the Department of Agriculture. In addition to crop damages, damages to livestock and to rural property, such as homes, roads, fences, and drainage, as well as to highways and railroads, are estimated from similar damages which occurred during floods of record. In urban areas, physical damages to civic, private, and industrial property, as well as to manufactured articles, loss of wages and income—all must be evaluated from intensive economic studies. As a rule, the economic comparison of benefits with cost show a much higher ratio in the industrial areas than in the agricultural ones. Benefit/cost ratios in the latter cases range from 1.5 up, whereas the East Side project has a ratio of approximately 33 to 1. The over-all average for all 22 projects is about 11 to 1. Benefits accruing to the 22 projects to date from damages eliminated in the floods since construction started total $33,000,000, although on the average less than one-half of the

projects were in operation and those for an average period of only 7 years of their 50-year economic life.

Status of Construction

Work has been initiated on 18 of the 22 projects. Of these, 8 are essentially completed and 4 more are well advanced. Of the 4 projects on which no work has been initiated, 1 is classed as inactive, 1 has been deferred pending further study which might result in changed levee alinement and protection to additional areas; on the third, planning is well advanced, while the fourth is scheduled for planning in fiscal year 1956. In all, 53-1/2 million dollars have been appropriated and expended of the total 102 million dollars required. Thus, on a fiscal basis, the 22 projects are approximately 52% complete, but on the basis of substantial protection constructed, approximately 75% has been provided. With adequate appropriations, it is estimated that the entire program can be completed in approximately 4 to 5 years.

SUMMARY

While completion of the 22 projects will provide adequate flood protection to the 323,000 acres of agricultural urban areas, with a population of 241,000 and a total value of improvements of 1-3/4 billion dollars, 3 additional areas still lack authorization for protection but studies thereon are now in the survey report stage. Of these, protection for the City of St. Louis is currently before Congress; modified protection for the St. Marys-Ste. Genevieve, Missouri, area to include approximately 9,000 additional acres and protection for the town of St. Marys is currently being studied and is essentially complete; and protection for the town of Ste. Genevieve is authorized for further study. Further study is also authorized to determine the need and economic justification for pumping facilities in the agricultural areas. If and when protection for these additional three areas and pumping facilities are authorized, protection for all portions of the Middle Mississippi Valley will have been provided. By then the hopes and wishes of those earliest settlers who chose St. Louis and the American Bottoms as a site for their homesteads will be joined with those who saw fit to band themselves together about 75 years ago to form the early levee districts into a full realization that the valley of the Middle Mississippi River could be adequately protected and developed into a safe, happy, and prosperous homeland.

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